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F. H. Newell

Irrigation in the United States

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IRRIGATION IN THE UNITED STATES.

IRRIGATION REPORTS

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UNITED STATES GEOLOGICAL SURVEY AND HYDROGRAPHY OF THE ARID REGION.

BY

F. H. NEWELL.

ABSTRACTED BY

OWEN CHARLES DALHOUSIE ROSS, M. INST. C.E.

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THE INSTITUTION OF CIVIL ENGINEERS.

SECT. II.—OTHER SELECTED PAPERS.

(Paper No. 2746.)

“Irrigation Reports¹ of the U.S. Geological Survey and Hydrography of the Arid Region,” (49 Plates, 7 Figs.).

By F. H. NEWELL.

Eleventh Census of the U.S., 1890. Washington 1892.

Abstracted by OWEN CHARLES DALHOUSIE ROSS, M. Inst. C.E.

OVER nearly one-half of the continent of North America, lying in a general north and south direction, west of the hundredth meridian, the rainfall is insufficient for the needs of man. It is a consequence of its topographical features, of the elevation and distribution of the mountain masses, that this arid land stretches in a general longitudinal direction instead of crossing the continent from west to east. In this vast area, which contains great deposits of mineral wealth and embraces several hundred million acres of agricultural land as rich as any on the globe, the hydrographic investigations of the Geological Survey chiefly consist of measurements of the water flowing in the rivers, or stored in the lakes, with the view of adding to the irrigated area (1) by a more intelligent utilization of the available supply, and (2) by increasing the quantity of water which might be drawn from those sources.

At present the area cultivated by irrigation (3,564,416 acres in 1889) is often so scantily supplied that each year the crops upon thousands of acres are injured, or lost, for lack of water at critical times. The common method of irrigating forage crops and the small grains is by flooding the land to a depth of 2 or 3 inches, or more; for other crops it is allowed to run along the furrows until the intermediate ground is saturated, and for fruit trees, or vineyards, small trenches are dug, or ploughed, from the distributing ditch to each tree, but there is no doubt that a larger area might be successfully cultivated by employing the present available supply with greater economy. One second-foot of water, or 1 cubic foot of water flowing 1 foot per second throughout the irrigation season, should suffice with care for the irrigation of

¹ The originals are in the Library Inst. C.E.

100 acres, and in California and Arizona it is even made to cover 120 acres, but, when wastefully used, it often only suffices for from 40 to 50 acres, or even less.

In many parts of the arid region there are fertile plains suitable for arable land so vast that by no possibility can they ever be brought under irrigation, but there are also very extensive areas which can be reached by canals, some of which are in course of construction or projected; and, moreover, the river floods bring down at irregular intervals great quantities of water which is allowed to run to waste. It is only a question of time, it may be five years or fifty, when storage dams will be built to hold back this flood-water and employ it in irrigation.

Before any steps can be taken towards the construction of such dams, ample and accurate information must, however, be collected on which to base conclusive estimates as to the success of the enterprise, and during the last few years numerous observations have been carefully collected respecting the various drainage basins. In a series of Tables and Diagrams which accompany the text, the daily discharge at a very large number of gauge-stations is tabulated, and everywhere testifies to an extraordinary variation in the flow of water. The following examples of minimum and maximum discharges are amongst the most remarkable:—

Name of State.	Name of River.	Minimum Discharge.	Maximum Discharge.	Period of Observations.
		Second-Feet.	Second-Feet.	
Idaho .	Weiser River . .	80	11,220	{ Year ended Feb. 28, 1891.
Oregon .	Owyhee	170	11,230	{ Year ended Mar. 31, 1891.
Montana .	Yellowstone . . .	285	11,915	{ Year ended Dec. 31, 1890.
Montana .	Missouri River . .	1,742	16,355	{ Year ended Dec. 31, 1891.
Texas .	Rio Grande . . .	45	16,620	Month of May, 1891.
California	Tuolumne	130	22,900	{ Six years, Nov. 1, 1878, to Oct. 31, 1884.
Idaho .	{ Snake River (Idaho Falls) }	2,286	50,450	{ Year ended June 30, 1890.
California	San Joaquin . . .	260	59,800	{ Six years, Nov. 1, 1878, to Oct. 31, 1884.
California	Sacramento . . .	5,050	160,000	{ Six years, Nov. 1, 1878, to Oct. 31, 1884.
Arizona .	{ Salt River (Arizona Dam) }	397	300,000	{ Year ended Feb. 28, 1891.

Bearing in mind that each second-foot of water is calculated to irrigate 100 acres, the figures in the fourth column, which indicate

flood-waters that are to a great extent now wasted, serve to illustrate the magnitude of the results attainable by their successful storage; but the building of the requisite works must necessarily proceed slowly, and the experience of the past few years shows that large sums will be required in order to insure solid and permanent construction. The mean variation between the maximum and minimum discharge at one hundred and thirty gauging-stations appears to be about 27 to 1, but on many rivers the flood-discharge does not exceed from 5 to 10 or 12 times the average of the whole year.

The principal rivers in the arid region, and the nature of the country through which they flow; the extent of the basins from which they derive their supply of water; the amount of discharge at various seasons; the area under cultivation and under irrigation, with many other particulars, are described very fully by the Author. The drainage area of the Rio Grande above its junction with the Pecos river is stated to be 145,200 square miles in extent, and that of the Colorado river 225,049 square miles. Of the 124,808 farms, comprising 36,899,000 acres, enumerated in the arid region in June, 1890, 42·13 per cent. contained land, on some of which crops were raised by irrigation in 1889, and the following Table shows the area of irrigated land, as well as the value of the products corresponding to each State or Territory.

States and Territories.	Number of Acres Irrigated in 1889.			Average Size of Irrigated Farms.	Value of Products in 1889.	
	Forage Crops.	Cereals.	Total.		Average Value per Acre.	Total Value.
				Acres.	£ s. d.	£
Arizona .	43,321	22,500	65,821	61	2 18 0	190,833
California .	474,233	530,000	1,004,233	73	3 19 2	3,975,000
Colorado .	625,735	265,000	890,735	92	2 14 8	2,434,583
Idaho .	154,005	63,000	217,005	50	2 13 11	584,583
Montano .	275,582	75,000	350,582	95	2 14 0	946,667
Nevada .	209,403	15,000	224,403	192	2 13 10	603,959
New Mexico	33,745	58,000	91,745	30	2 13 4	244,583
Oregon .	124,544	53,400	177,944	56	2 17 11	515,208
Utah .	148,473	115,000	263,473	27	3 15 2	989,583
Washington	28,299	20,500	48,799	47	3 11 2	173,750
Wyoming .	210,676	19,000	229,676	119	1 14 4	394,791
Total .	2,328,016	1,236,400	3,564,416	67	3 2 0	11,053,540

Of the irrigated area 50·36 per cent. was in farms under 160 acres ($\frac{1}{4}$ square mile) and 49·64 per cent. was in farms of 160 acres and upwards.

The preceding statistics concerning the acreage and value of land and products have been taken from the enumerators' returns for each agricultural holding, while the following facts have been obtained by direct correspondence with farmers by means of special schedules addressed to each irrigator. These schedules contained questions intended to cover facts concerning the location of irrigated land, the character of the water-supply, the cost of irrigation, methods of using the water, necessity of irrigation, the use of artesian wells and pumps; also the location of canals or irrigating ditches, size and cost, methods of distributing the water, &c. In all about thirty thousand replies have been received, and from these, after proper tabulation, certain averages have been drawn, the principal of which are as follows:—

(1) The average first cost of bringing water to the land has been £1 13s. per acre, this average being derived from the statements of all persons who have constructed ditches or have purchased water-rights from canal companies, or others. The highest average is in the case of California, where the most thorough and expensive systems for saving and distributing water have been constructed; the lowest in Wyoming, where enormous areas have been covered with water by means of ditches quickly and cheaply constructed by means of plough and scraper, costing little more than one-fourth what has been spent in California.

(2) The average value per acre of these water-rights, wherever they can be considered independently of the value of the land, is £5 6s. 4d., but in many localities the water-right cannot be taken from the land without depriving the latter of its entire value, for without a water-supply the land is worthless. Taking, however, those cases in which water-rights are transferable and are sold, or treated like other pieces of property, the difference between £1 13s. and £5 6s. 4d., or £3 13s. 4d., may be regarded as the average profit per acre to the creator of the water-right.

(3) The average annual cost of repairing and keeping ditches in good order, or otherwise maintaining the water-right, is 4s. 6d. per acre.

(4) The cost of bringing the land under cultivation beyond the expense for water, but including fencing, &c., has varied considerably. In California, owing to the greater amount of labour spent upon it, the average reaches £3 12s. 10d., but the cost throughout the arid region has averaged £2 10s. 6d. per acre. Applying these averages—which are given in detail for each state and territory—with proper modifications, to the total acreages of those States, it would appear that the approximate first cost of irrigation in the

entire region has been £6,168,960, and, the total water-rights in 1890 being valued at £19,669,160, the increase in value or profit on the expenditure incurred in works of irrigation appears to have amounted to £13,500,200, or 218 per cent. The proportion in which the cost and profits of the irrigation in the arid region apply to each State is shown in the following Table:—

State or Territory.	First Cost of Irrigation.	Value of Water-rights in 1890.	Increase or Profit.
	£	£.	£.
1. California	2,709,375	8,217,910	5,508,535
2. Colorado	1,326,875	5,281,250	3,954,375
3. Utah	579,166	1,473,333	894,167
4. Montana	338,125	1,098,542	760,417
5. Wyoming	266,875	791,875	525,000
6. Nevada	260,625	773,750	513,125
7. Idaho	214,375	595,833	381,458
8. Oregon	172,084	573,958	401,874
9. New Mexico	106,666	349,792	243,126
10. Arizona	96,875	172,500	75,625
11. Washington	41,044	133,750	92,706
12. Sub-humid region . .	56,875	206,667	149,792
Total	6,168,960	19,669,160	13,500,200

The results shown in the above Table apply to irrigation constructions or rights considered apart from the land. Adding to the first cost of the land which was irrigated in the census year that of its cultivation, and of the building of fences and other necessary operations, as well as the cost of bringing water to it, the Author arrives at an approximate estimate of the expenditure upon the total irrigated land amounting to £16,143,750, whereas its value on the 1st of June, 1890, as derived from the statements of a majority of the owners, was estimated at £61,843,750, thus showing an increase of £45,700,000, or 283·08 per cent.

The average cost of irrigating canals under 5 feet in width, including headworks, flumes, &c., was £100 per mile; of those from 5 to 10 feet in width, £339 per mile; and of those exceeding 10 feet in width, £1,167 per mile.

A separate Census Bulletin, dated the 17th of May, 1892, deals with the subject of artesian wells for irrigation. The total number at the time when the census was taken (June 1890) on

farms in the arid and sub-humid regions was 8,097, representing an estimated aggregate cost of £414,283. Complete statistics concerning the depth, cost, discharge and other features of 2,971 of these wells have been obtained from the owners, from which it results that the average depth per well was 210·41 feet, the average cost per well £51 3s. 4d., the total discharge of water per minute 440,719·71 gallons, or 54·43 gallons per well per minute, the average area irrigated per well 13·21 acres, and the average cost of water per acre irrigated £3 17s. 4d. More than half of these wells are in California, where 38,378 acres of agricultural land were irrigated by artesian water. The average cost of water per acre by ordinary means of irrigation was £1 14s. 0d., which is less than half of the cost by artesian wells; and it should moreover be borne in mind that a great many attempts, aggregating perhaps thousands, have been made to obtain flowing water, which have been unsuccessful.

Artesian wells result usually from the drilling of porous strata filled with water, which is held from escaping by impervious rocks both above and below, the hydrostatic pressure on this water due to the inclination of the bed being sufficient to force it to the surface, but for more exact definition the Author refers to a Paper entitled "The Requisite and Qualifying Conditions of Artesian Wells," by T. C. Chamberlain, in the fifth Annual Report of the U.S. Geological Survey, as being, without doubt, the most comprehensive description of this subject. Most of the wells are drilled into nearly level unconsolidated rocks of late pliocene or pleistocene epochs, but the deeper wells in the States of Dakota and Texas, which are often 1,000 feet or more in depth, obtain their supply from the base of the cretaceous formation, and these are the largest and probably the most permanent artesian areas of the country. The greater part of the water which has been raised in this way is used upon small gardens in the vicinity of houses, and for fruit and shade trees, for watering lawns, and for raising grass either for pasturage or hay; for the ordinary field crops it has been employed only to a small extent.

A Table is given showing the number of artesian wells in each county of each State, together with the depth of the deeper and shallower wells and the average depth, and the cost and discharge in gallons per minute of those wells for which statistics were obtained from the owners.



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